Level-0 Calorimeter and L1 Global Triggers WBS 6.8.y.1 and 6.8.y.3

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U.S. ATLAS HL-LHC Upgrade NSF Conceptual Design Review

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Outline

- System experts and Principle Investigators
- System Overview
  - Current (Run-2) System, Phase-1 upgrade and Motivation for Upgrade
  - ATLAS Upgrade Plans
- Proposed U.S. HL-LHC Upgrade Scope
  - Work Breakdown Structure and Contributing Institutes
  - U.S. Deliverables
- Ongoing R&D
  - Plans to Construction Project
  - Funding Needed
- Construction Project Management
  - Construction Project Budget and Schedule
  - Risk, Contingency, and Quality Assurance
- Closing Remarks

About the Expert

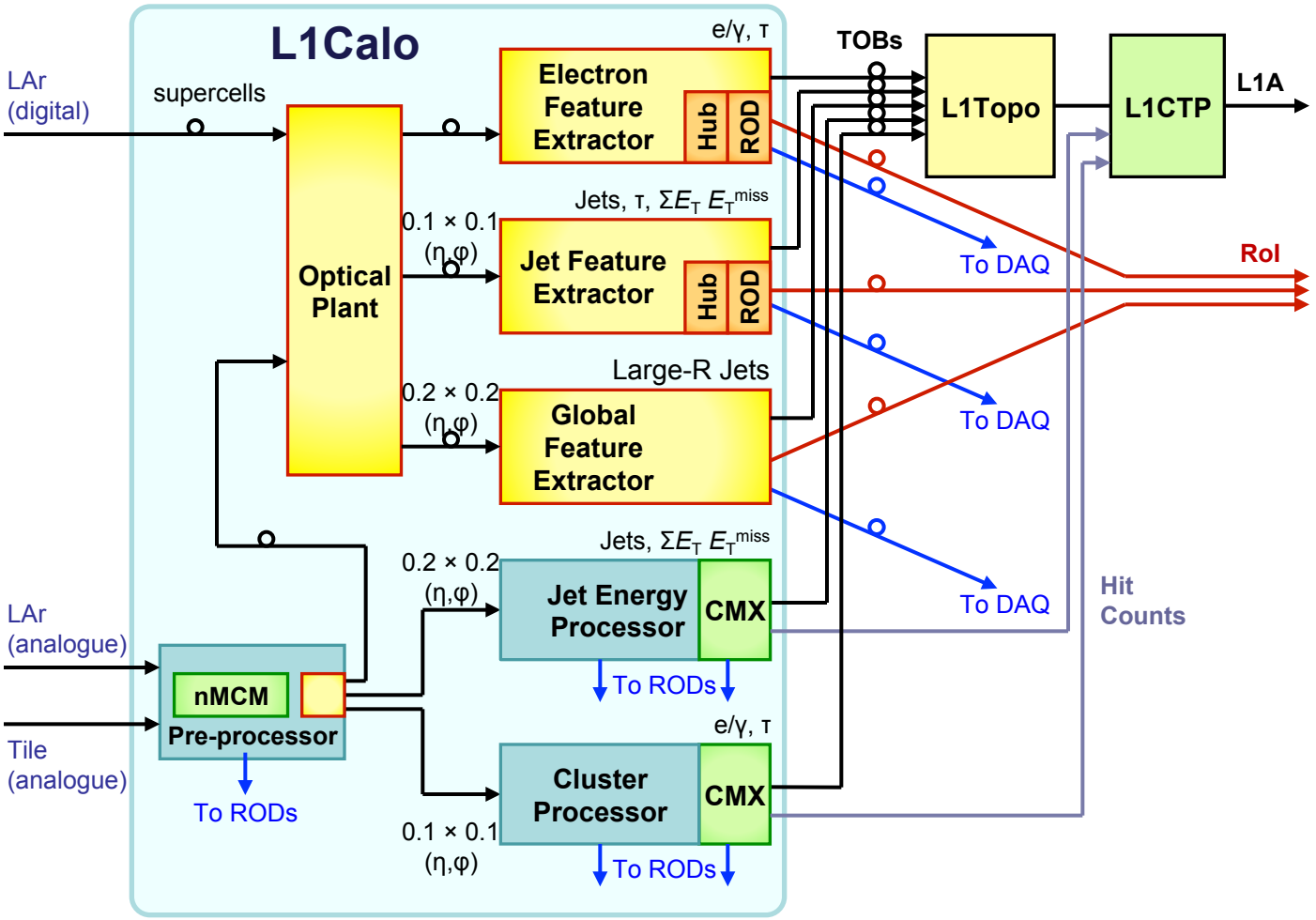
- Wade Fisher, Associate Professor, Michigan State University
  - Member of ATLAS collaboration and TDAQ group since 2012
  - L3 manager for Phase 1 upgrade project: FEX ATCA Hub module
  - MSU also built and commissioned Phase 0 upgrade L1Calo module: Common Merger Module Extended (CMX)
    - Engineers Dan Edmunds, Philippe Laurens, Yuri Ermoline, Pawel Plucinski

- Additional Primary Contributions
  - Sizable list of TDAQ experts with significant upgrade experience
  - L0 Calo: Reinhard Schwienhorst (MSU), Hal Evans (Indiana)
  - L1 Global: WF (MSU), Stephanie Majewski (Oregon), Elliot Lipeles (Penn), ….

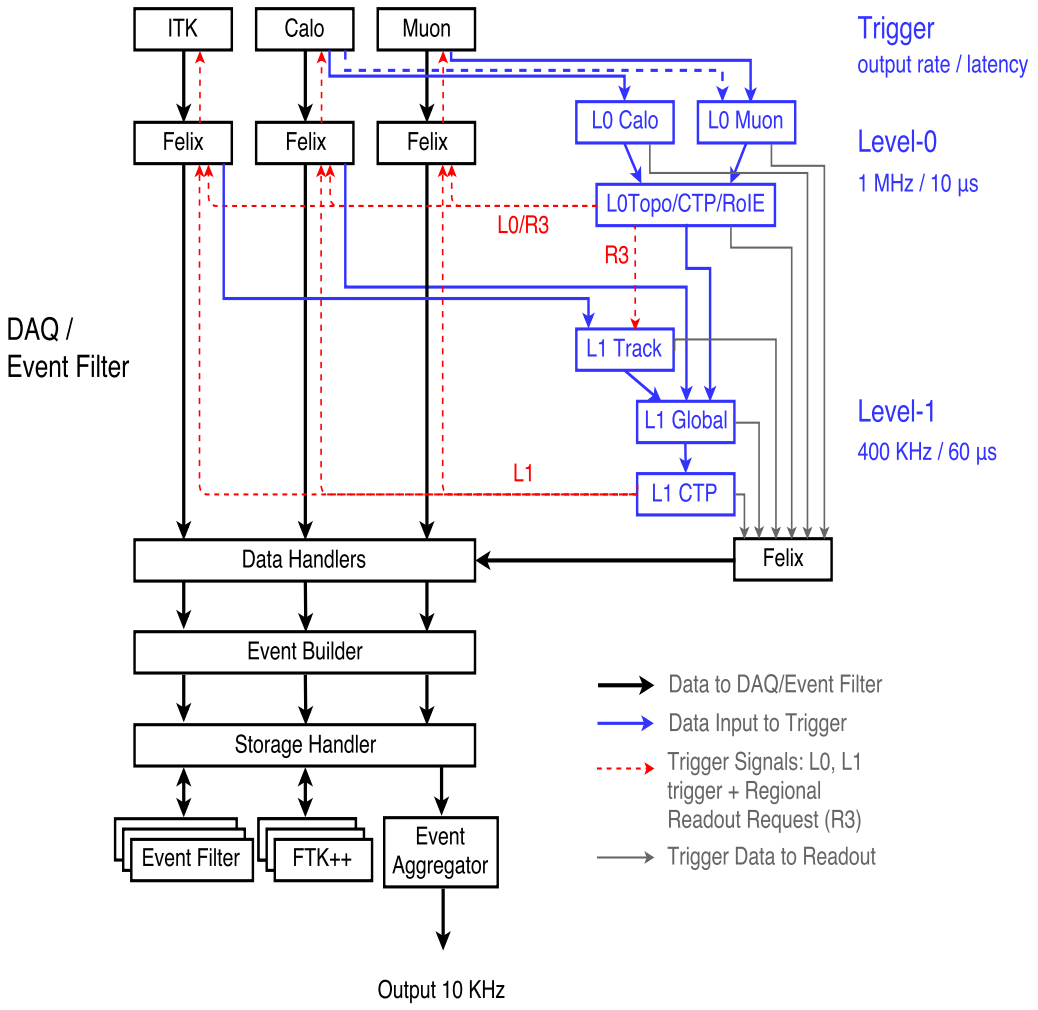
About the Institutes

- Michigan State University
  - Member of ATLAS since beginning of US participation
  - Long history of trigger construction projects and strong EE team
    - Engineers Dan Edmunds, Philippe Laurens, Yuri Ermoline, Pawel Plucinski
- Oregon
- Indiana

Phase 1 Upgrade Overview

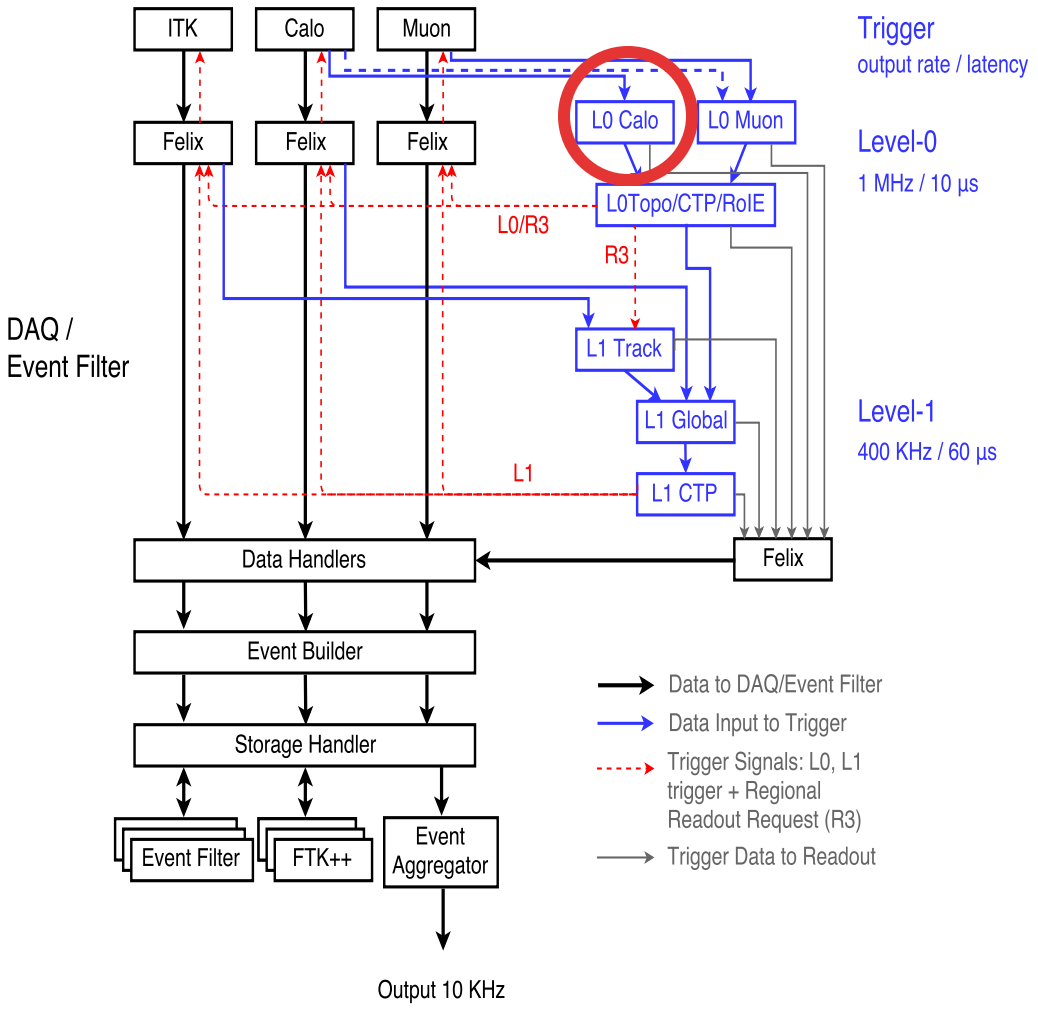


HL-LHC System Upgrade Plans



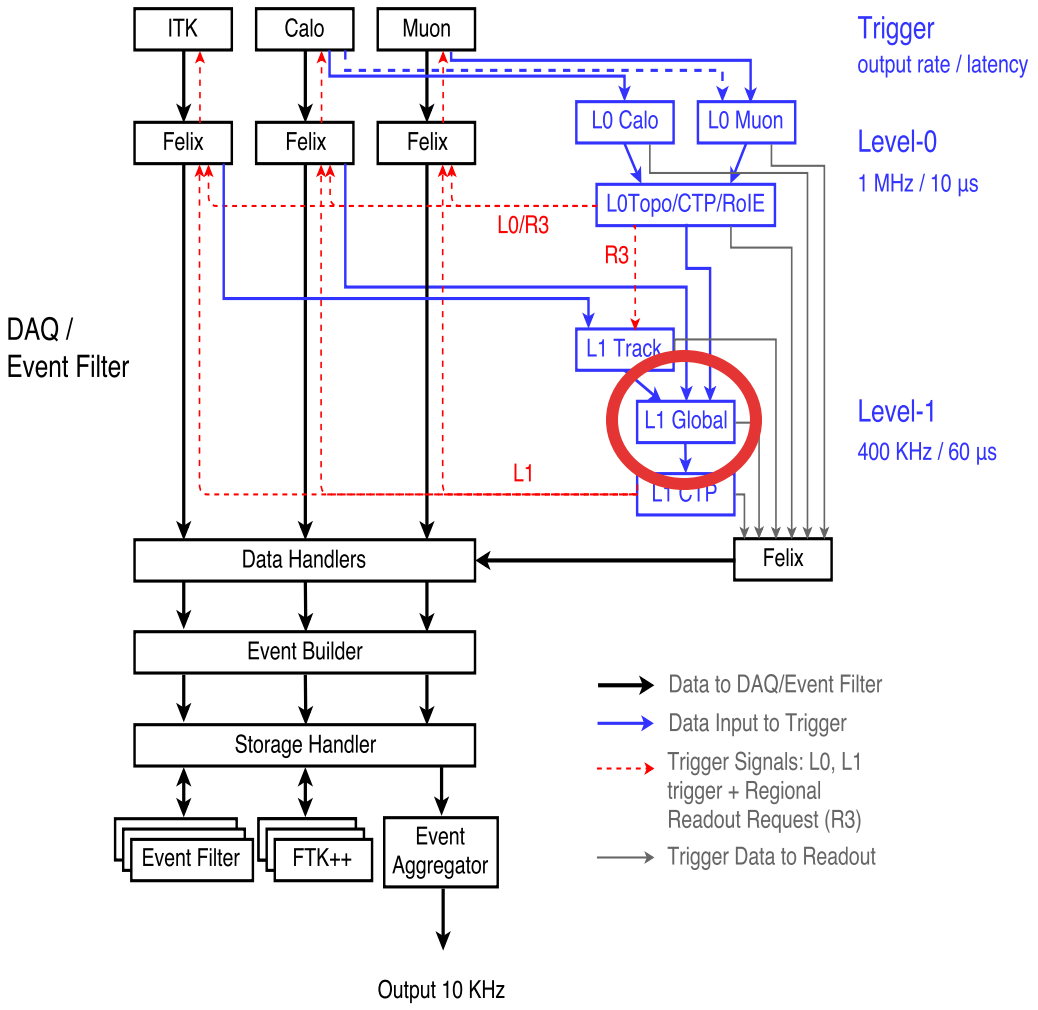
- Two-level hardware system
  - Phase-1 L1 system becomes HL-LHC L0 system
  - High precision Muons (MDT) added to L0 system → improves efficiency
  - L0 Rate is now 1 MHz
    - Allows in more physics
  - L1 system uses tracks and full granularity calo in regions of interest to improve reject before HLT
    - Tracking 10% of data at 1 MHz
  - Full detector tracking for 100 KHz events in HLT → mitigates pile-up for hadronic triggers

HL-LHC System Upgrade Plans



- Level-0 Calorimeter Trigger
  - Phase-1 L1 system becomes HL-LHC L0 system
  - Tile input to L0Calo will be new digital input from Tile preprocessor
  - New Tile Optical Plant needed for new Tile front-end electronics mapping / interface
  - gFEX firmware needs to be upgraded for
    - New Tile inputs,
    - Modified algorithms for higher pile-up/new inputs
    - New output requirements for L0Topo and DAQ

HL-LHC System Upgrade Plans



- Level-1 Global Trigger
  - L1 Global system aggregates inputs from Calo, Muon and Track triggers
  - Processes fine-granularity calorimeter inputs for improved siganatures
  - Evaluates combined trigger algorithms using 'global' information
  - Proposed NSF scope focuses on current US hadronic trigger experience to support processor algorithm design
    - Energy clustering and jet identification
    - Global calorimeter quantities (MET, HT)
    - Track-based pileup rejection

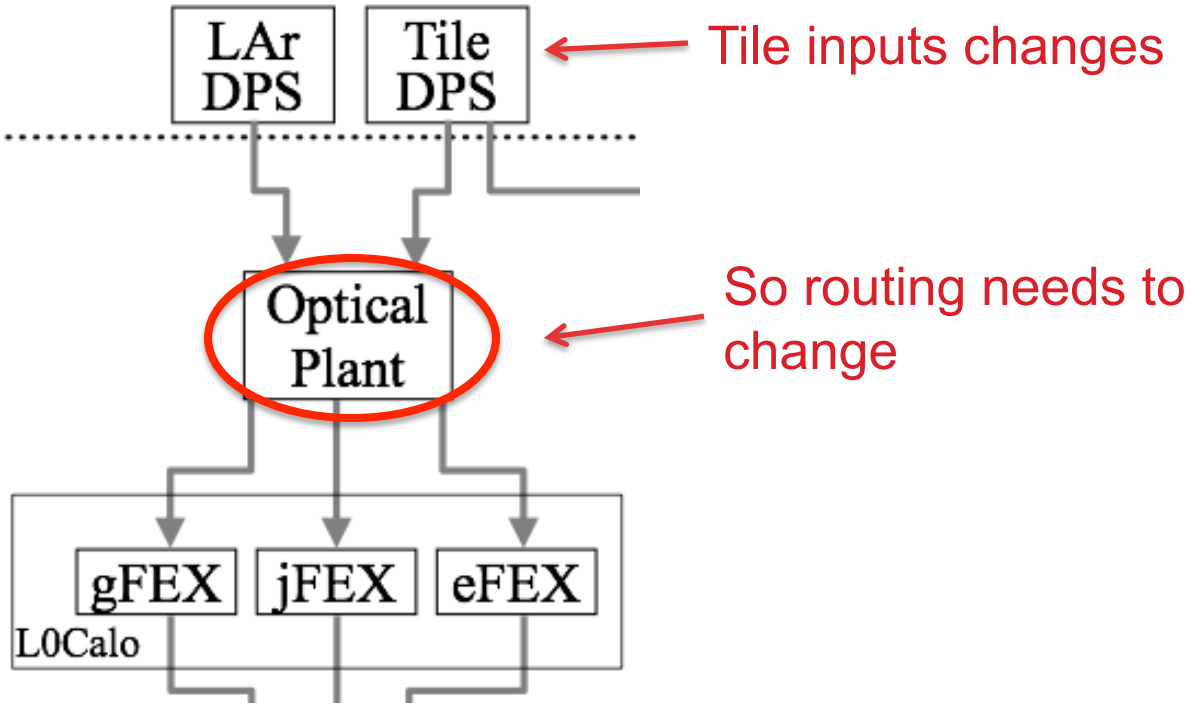
Proposed NSF Scope

- 6.8.y.1 L0 Calo
  - Rebuild fiber optic input router because of changes to tile inputs
  - MSU is building Phase-1 system this capitalizes on their unique expertise
  - **Institutes**: Michigan State (MSU)

- 6.8.y.3 L1 Global Processing
  - L1 Global algorithms are where the rate reduction from 1 MHz to 400 KHz happens
  - 4 firmware algorithms focused on hadronic triggering:
    - Offline-like energy clustering and jet construction, global quantities (MET, HT), and track-based pile-up rejection
  - This builds on US experience with Phase-1 "gFEX" system which does global hadronic triggering in what will be L0
  - **Institutes**: U Chicago, U Indiana, Louisiana Tech, Michigan State, U Oregon, U Pittsburgh

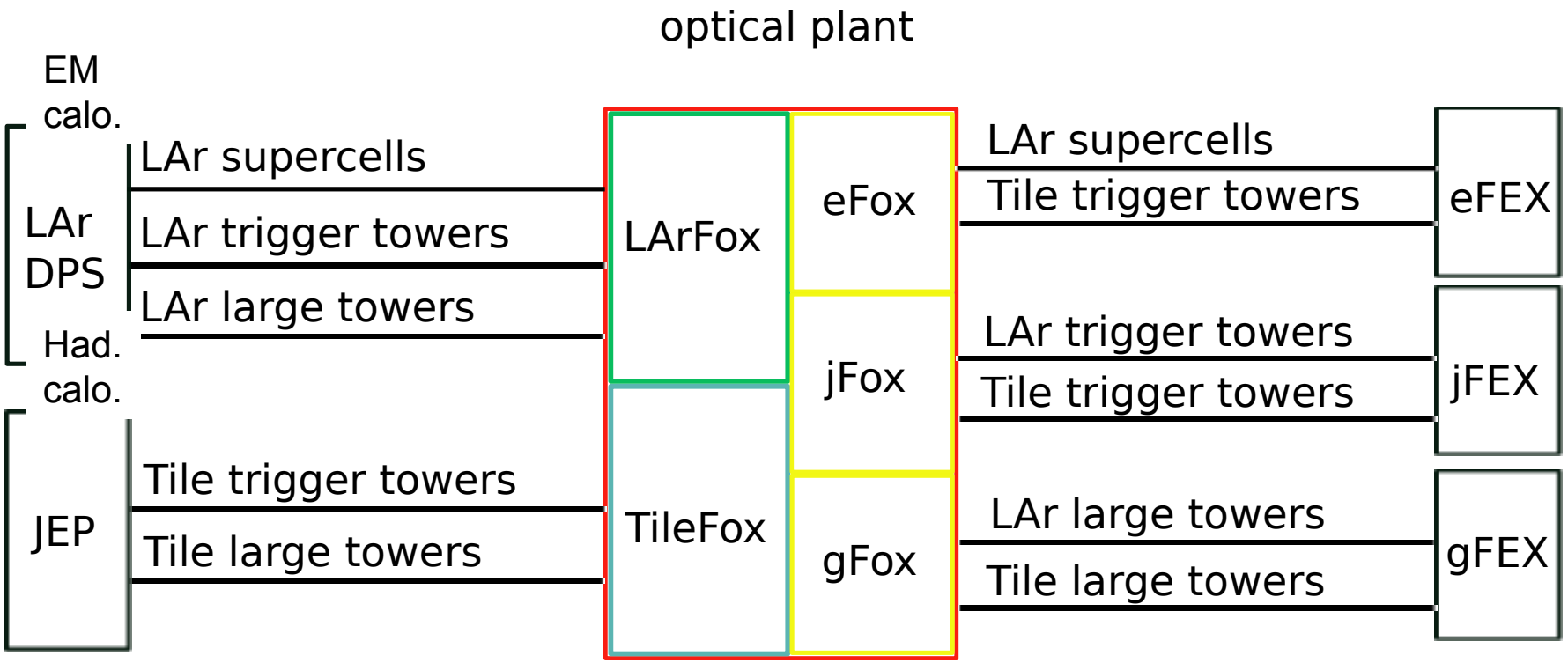
6.8.y.1: L0 Calo Fiber Optic Plant

- Rebuild the Phase-1 Fiber Optic plant to accommodate the change to the tile electronics
- Builds on unique MSU experience with fiber routing and splitting

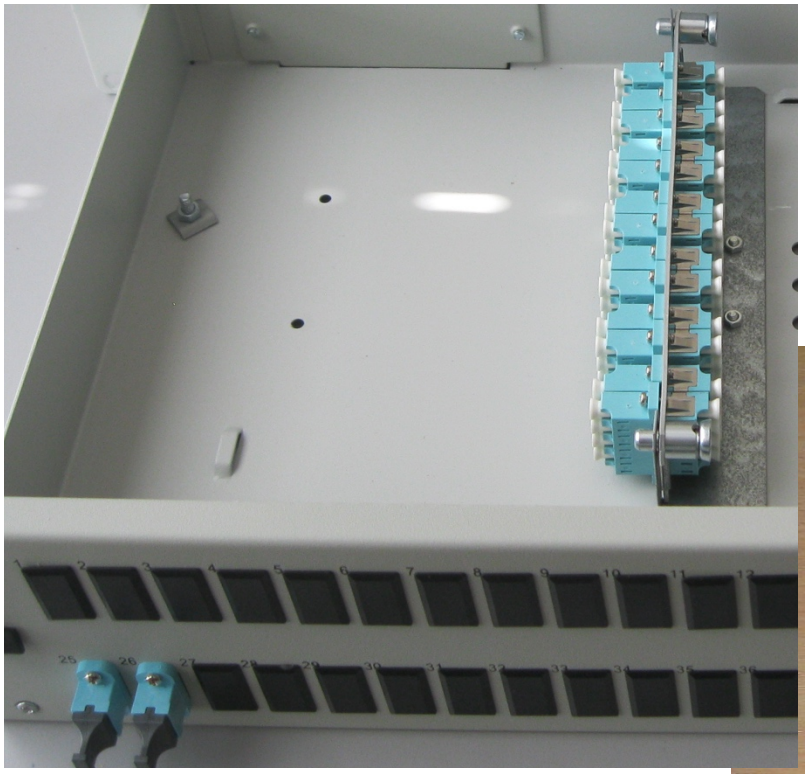


FOX – Fiberplant

- Phase-1 Deliverable: Fiber-Optic eXchange
  - Project underway at MSU
  - Well-understood technical challenges

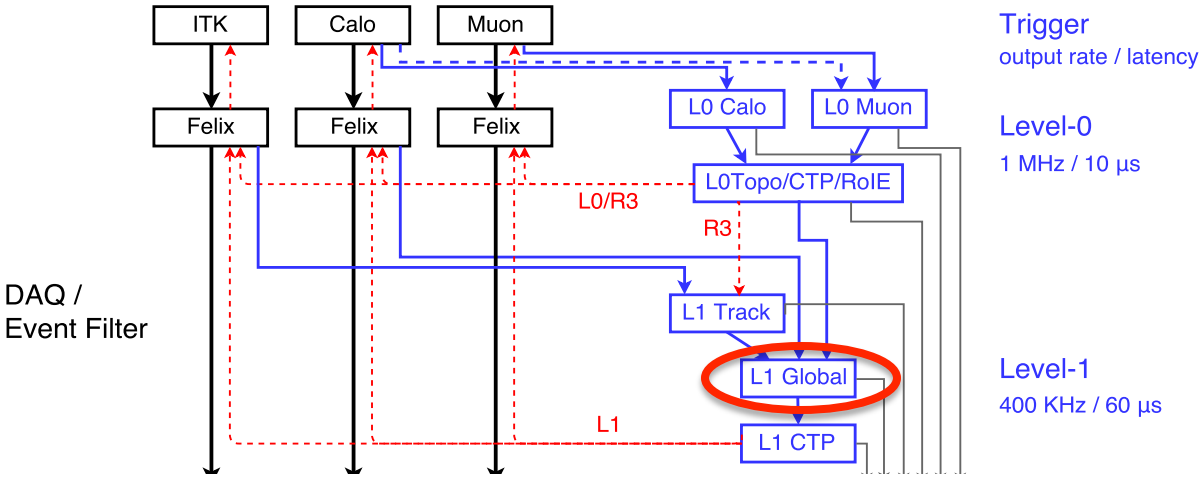


Version-1 Optical Fiber Plant



6.8.y.3: L1 Global Processing

- Deliverable is firmware that runs on the L1 Global Processor
  - The focus is on hadronic triggering with 4 related items
    - Offline-like "topological clustering" of calorimeter energy
    - Offline-like jet finding
    - Global quantities: Missing energy, sum of jet pTs (HT), and MHT
    - Track-based pile-up rejection for multijet and global quantities
- Follows Phase-1 experience with the gFEX system
  - gFEX is global quantities and fat-jets at what will be L0 in HL-LHC



Ongoing R&D Efforts

- R&D Efforts underway using pre-MREFC funding

- 6.8.y.1: L0Calo Optical Plant
  - Phase-1 L1Calo optical plant R&D effort eliminates need for dedicated Phase-2 R&D effort.
    - Highly similar design to be implemented by the same PI/engineers

- 6.8.y.3: L1Global Algorithms
  - Current experiences with Phase-1 gFEX algorithm development useful
    - Studies of global quantities, jet substructure, large-R jet pileup subtraction
  - Dedicated R&D studies of topological clustering algorithms underway
    - Characterizing clustering algorithm limitations on FPGA targets
    - Latency/resource/resolution studies help guide hardware and algorithm choices
    - Same engineers expected to contribute to Phase-2 efforts

Budget Estimation

- WBS 6.8.y.1: L0Calo Optical Plant
  - Primarily based on current Phase-1 Fiber Optic Exchange module
  - Well-understood technical scope and costs
  - Phase-1 experiences will reduce overall risk to both schedule and cost

- WBS 6.8.y.3: L1Global Firmware Algorithms
  - Based on current Phase-1 gFEX algorithm development
    - L1Calo gFEX module: Global Feature Extractor
  - Similar level of complexity and schedule demands
  - Expert-level estimation for anticipated differences wrt gFEX

Risks (To be updated)

- General sources of risk
  - Changes or delays in system definition
  - Changes or delays in interfaces with other sub-systems
  - Performance of available FPGAs or other processors different than expected
  - Off project physicist effort is insufficient
- Mitigation
  - In general, mitigation is system specific
  - In some cases, development can continue even when system definitions are not complete
  - Performance issues can be handled by reducing target efficiencies if necessary
  - Off project manpower issues can be addressed by expanding the range of collaborators (in US and out)

Closing Remarks

- US Deliverables
  - 6.8.y.1 L0 Calo fiber optic plant for new tile output
  - 6.8.y.3 L1 Global Processing algorithms for hadronic objects

- This package with have a high impact on the ability of ATLAS to maintain low threshold single lepton and hadronic triggers
- Budget and Planning are based on Phase-1 experience

Backup